Ocean Response Coastal Analysis System (ORCAS)

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LONG-TERM GOALS

Our long-term goal is to develop instrument systems for coherent, real-time monitoring of multiple biological, physical, chemical, and optical parameters within the ocean, in 3-dimensional space and time. These systems must be readily deployable, yet provide real-time data with sufficient vertical and horizontal resolution for determination of the coastal environmental response to episodic events such as storms, nutrient inputs, hypoxia and algal blooms.

OBJECTIVES

Our primary objective is to develop, test and demonstrate a system combining ship-deployed and autonomous bottom-up profilers that will allow coherent, finescale profiling of multiple oceanographic parameters in 3- dimensional space and time. New sensors for inherent optical properties (IOP) and *in situ* nutrient analyzers will also be developed, tested and integrated into the new profiler packages. The system will be designed to be rapidly deployed to quantify the fine-scale biological, physical, chemical, and optical responses of coastal systems to episodic events of interest or opportunity, such as storms, harmful algal blooms, chemical spills, and the onset of hypoxia or anoxia.

APPROACH

The profiling system will be based on a recently tested technology that uses small underwater winches to deploy a CTD/optics package to profile temperature, salinity, density, oxygen, spectral absorption and transmission at centimeter scales. The existing system is semi-autonomous and connected to shore by a cable that provides for power and data transfer. The new system will be self-contained and able to operate autonomously with real time control and data transmission by acoustic modem or radio telemetry. Data processing will occur on board the profilers so that the transmitted data can be made widely available without extensive post processing. Two types of underwater winch profilers are being developed. First, we are developing a small, low cost, highly integrated profiler that can support a limited number of physical, bio-optical sensors and chemical analyzers. This ‘mini-profiler” package can be deployed singly or as an array of several profilers, to provide broader spatial coverage. This small

package will involve a significant reduction in instrument weight and volume without reducing fidelity or resolution, as compared to current state-of-the-art devices. Second, we will develop the "maxi-profiler", which will allow the bottom-up deployment of a comprehensive selection of multi-parameter, high resolution, high data rate physical, optical, biological and chemical sensors and analyzers. The maxi-profiler will be designed to with considerable flexibility in the types of sensors that can be supported. The maxi-profiler can also be moored within an array of mini-profilers. After technical development and evaluation, the new optical sensors, chemical analyzers and profilers will be tested in the field, to insure reliability and utility, and to demonstrate their applicable functionality to the oceanographic community.

An important aspect of our approach is to use a partnership between academia, government and industry to achieve our objectives. The other partners are Alfred Hanson (SubChem Systems), Casey Moore and Ron Zaneveld (WET Labs), Alan Weidemann (NRL-Stennis), LCDR Kimberly Davis-Lunde (Commander, Naval Meteorology and Oceanography Command) and Richard Green (Environmental Protection Agency Gulf Ecology Laboratory). Field testing and real-time demonstration will be an integral part of this project. The field testing will be conducted in concert with ongoing URI, EPA and Navy investigations focusing on the impacts of episodic events (wind, storms, tides, hypoxia) on coastal plankton ecology and underwater optics. The profiler field tests and demonstrations will be planned to insure that the partners end up with a reliable design that not only supports their own research interests and objectives, but also leads to commercial profiler systems that can be used by the basic and applied research communities.

WORK COMPLETED

We hosted a four day engineering design meeting at URI during the week of October 4, 1999. This meeting was attended by Casey Moore (WET Labs), Alex Derr (WET Labs), and Dave Romanko (WET Labs), Alfred Hanson (SubChem Systems), Eugene Morin (Seems), Margaret Dekshenieks (URI), Jim Sullivan (URI) and Percy Donaghay (URI). Detailed engineering specifications were developed for the mini-profilers. A draft report including these specifications and initial designs was prepared by Casey Moore and Alfred Hanson and circulated to the other PIs.

We hosted an initial meeting of the partnership at URI on November 12, 1999. This meeting was attended by Casey Moore (WET Labs), Alan Weidemann (NRL), Alfred Hanson (SubChem Systems), Eugene Morin (SEEMS), Richard Green (Environmental Protection Agency Gulf Ecology Laboratory), James Eckman (ONR), Margaret Dekshenieks (URI), Jim Sullivan (URI), and Percy Donaghay (URI).

WET Labs hosted two engineering design meetings. The meeting on April 10-11 was attended by Casey Moore (WET Labs), Alex Derr (WET Labs), Dave Romanko (WET Labs), Ron Zaneveld (OSU), Alfred Hanson (SubChem Systems), Eugene Morin (Seems), Margaret Dekshenieks (URI), Jim Sullivan (URI), and Percy Donaghay (URI). Initial system designs were revised based on progress in developing sensors, data processors/controllers, and deployment systems. The meeting on June 28-30 was attended by Casey Moore WET Labs), Alex Derr (WET Labs), Dave Romanko (WET Labs), Jim Sullivan (URI) and Percy Donaghay (URI). This meeting focused on designing an interim system that would allow field testing of the new sensors and deployment techniques starting in October 2000.

SubChem systems and WET Labs have made major progress in developing the submersible, multi-channel *in situ* chemical analyzer that is a key new technology in the ORCAS profilers. SubChem has developed an underwater reagent delivery module that transforms underwater optical detectors made by

WET Labs into sensitive chemical analyzers designed to provide high-resolution vertical and horizontal profiles of nutrients in real-time (1 sample per second). The analyzers are also designed to determine nutrients and accurately at trace levels (nanomolar to micromolar). This module has the control and flexibility to allow it to be used for measuring a variety of nutrients and trace metals including nitrate, nitrite, ammonia, urea, phosphate, silicate, iron (II), iron (III) and copper. The chemical concentrations are determined by continuous flow analysis with spectrophotometric and fluorometric methodologies that have been optimized for rapid *in situ* measurements. Techniques have been developed that allow the *in situ* calibration required for autonomous operation. The operation and data acquisition for the instrument is computer-controlled and user-friendly. The concentration readings for nutrients are instantaneously displayed on the computer monitor. A version of this system has been developed that can be co-deployed with standard oceanographic electronic sensor packages (CTD) for vertical and/or horizontal (to-yo) profiling. This initial system is powered and controlled from the surface via a standard cable.

Working in collaboration with SubChem, WET Labs has developed a new generation of absorption cells for the submersible nutrient analyzer that dramatically decreases volumetric requirements for the analyzer. Prototype versions of the nutrient analyzer incorporated 5 mm diameter flow cells that were 25 cm in length. The new optical cells incorporate 1 mm diameter cells that are 15 cm in length. This results in an approximate forty times reduction in required volumetric flow for the sensors. This reduction in volume, in turn, dramatically reduces heating requirements, pump flow rates, reagent use, and over all package size. The new cells have been tested and shown to have slightly improved sensitivity over the larger prototypes. This development represents a major breakthrough in our efforts to reduce the size and power requirements of the analyzers to the point where they can be incorporated into the autonomous, battery powered ORCAS profilers.

The URI group has made significant progress in developing a new generation of underwater winches that have the energy efficiency, reliability and longevity required by ORCAS. The heart of these winches is a digitally controlled brushless DC motor that is widely used in commercial and military applications. These motors have built-in sensors and a digital controller that will allow us to control and evaluate their performance without us having to build a separate controller (as originally proposed). One of these motors is being incorporated into a new winch that that will be tested this fall in Narragansett Bay. A second has being used by WET Labs in developing their integrated control systems.

We have worked with WET Labs to develop an interim system configuration for the mini-profilers that would allow field testing of components as they are developed. We have provided our existing ac-9s (spectral absorption and attenuation meters) and SeaLogger CTDs. WET Labs has modified our ac-9s to incorporate prototype package controllers they have developed. This interim system provides for concurrent sampling of spectral absorption and attenuation (9 wavelengths), flow through the ac-9, conductivity, temperature, depth, dissolved oxygen, volume scattering function, chlorophyll fluorescence, and when ready, a 4 component nutrient analyzer. This set of measurements encompasses the original suite envisioned for the mini-profiler specified at our initial engineering design meeting. While some sensors and controllers will get upgraded over the next year and the profiler package itself will evolve into a more hydrodynamic and smaller frame, this initial system will allow us to move into full scale wet testing well ahead of the original schedule. One of these configurations packaged with the controller has been delivered to URI for integration with the winch and three more will be shipped by the end of September.

Oracle software has been chosen for the creation of a relational database capable of storing, retrieving and visualizing the large data sets that will result from the Ocean Response Coastal Analysis System. Oracle software runs on PCs, and thus will be readily portable to the field. In addition, Oracle software is developed with an internet-ready platform for building and deploying Web-based applications. Margaret Dekshenieks (URI) has completed the first phase of training in Oracle SQL and PL/SQL, which is the programming language used to access the Oracle database. The second phase of training which involves enterprise data base administration, will occur in November 2000. Oracle is currently being used for data basing by partners at the Naval Meteorology and Oceanography Command (Stennis Space Center).

We subcontracted the development of the telemetry system to a local engineering firm (Seems, LLC) that has considerable experience in this area. They have design a system that includes a radio modem, GPS receiver, data interface, and power management module. The core of the system is 2.4GHz spread spectrum radio transceiver, capable of 5 mile LOS range, and 1MBaud data rate, allowing "real-time" data logging and control of up to 50 profilers. This system is extremely small and low cost, yet highly reliable. The radio is user configurable for master/remote modes, and can use programmable sequenced hopping to transmit data over longer distances than can be reached directly.

RESULTS

Field tests of the submersible chemical analyzer conducted in Narragansett Bay in December 1999 and August 2000 have demonstrated that the system can be used in field systems. The SubChem submersible chemical analyzer was deployed with a SeaLogger CTD equipped with sensors for oxygen, pH, chlorophyll a and light intensity. The submersible chemical analyzer was initially developed and utilized for the determination of nitrite and iron (II) in seawater (Hanson and Donaghay, 1998; Hanson, 2000). High resolution continuous profiles have been collected for nitrate, nitrite, iron (II) and iron (III). Sensitivities of 1-2 nm were confirmed using in situ calibrations. Analytical technologies were also evaluated for ammonia and urea determinations with this system. These results were presented by Hanson at the OCEANS 2000 MTS/IEEE Conference, and are published in the proceedings of that meeting (Hanson, A. K., 2000). The development of this system has now reached a point where a commercial version (the *SubChemPak Analyzer*) was introduced at the conference.

IMPACT

There are many scientific, technical, environmental, and defense related applications for the autonomous moored profilers and compact oceanographic sensors that we are developing with this NOPP funding. It is predicted that the development, field demonstration and commercialization of this innovative technology will have a substantial impact on the way we observe ocean variability, and our understanding of the significant role that episodic events play in the dynamics of coastal environments. There clearly is a substantial potential for very broad support and utilization of the technology and results garnered from the proposed NOPP partnership effort.

TRANSITIONS

This project has been specifically designed to rapidly transition the results of our past and proposed research and technology development to users in the Navy, EPA, industry and oceanographic research communities. Our partnership with Alan Weidemann (NRL-Stennis) and LCDR Kimberly Davis-Lunde (Commander, Naval Meteorology and Oceanography Command) are specifically intended to insure

rapid transition of the results to the Navy. As part of this effort, Percy Donaghay presented a paper in September 2000 at the MTS Gulf Coast meeting held in Stennis, MS. Our partnership with Richard Green (Environmental Protection Agency Gulf Ecology Laboratory) is designed to insure transitioning to the EPA and other users in the field of environmental assessment. As part of this effort, Alfred Hanson presented a paper on new *in situ* technologies for monitoring and predicting harmful algal blooms at the Fifth Symposium of the EPA-NHEERL on Indicators in Health and Ecological Risk Assessment held at Research Triangle Park, NC, June 6-8, 2000. Our partnership with Casey Moore and Ron Zaneveld (WET Labs) and Alfred Hanson (SubChem Systems) is designed to insure the development of instruments that will be commercially available to other groups. In addition, we are collaborating with NUWC to insure the rapid transition of sensor and deployment technologies for use in their AUV programs (see related project 3).

RELATED PROJECTS

1. Percy Donaghay (URI): ONR Biology and Chemical Oceanography Program funding for studies of the biological - biological, physical - biological and chemical - biological interactions that control the initiation, maintenance and dissipation of plankton patches.

2. Margaret Dekshenieks (URI), Thomas Osborn (JHU), Percy Donaghay (URI) and Ann Gargett (IOS): ONR Physical Oceanography funding examining large scale physical forcing of thin layer dynamics.

3. Alfred Hanson (SubChem & URI): Internal, state (URI-OTCE), and NOAA funding to develop and commercialize submersible chemical analyzers. Alfred Hanson and James Miller (URI) are collaborating with NUWC (Newport, RI) and WHOI on the integration and application of a chemical analyzer (SubChem Analyzer) and high-frequency forward-looking sonar systems to the REMUS AUV. The integrated multi-sensor systems (ADCP, CTD, OBS, SONAR and SUBCHEM) will be used synergistically to develop, evaluate and implement various AUV search algorithms to map and locate the source of chemical plumes in coastal waters.

5. Alan Weidemann (NRL): Optical/physical coupling, Spectral Signatures Program Co-PI (NRL funded).

6. Richard Greene (EPA-GED): Investigations of environmental factors regulating HAB growth dynamics, life cycles, and toxicity (internal EPA-GED), effects of zooplankton grazing and co-occurring bacteria on HAB dynamics (internal EPA-GED).

PUBLICATIONS

Hanson, A. K., 2000. A new *in situ* chemical analyzer for mapping coastal nutrient distributions in real time. OCEANS 2000 MTS/IEEE Conference Proceedings, 3:1975-1982.